REVERSE OSMOSIS

PILOT PROGRAM

AT

DARE CANDY

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Report Prepared By:

CH2M Hill Engineering Ltd.
Waterloo, Ontario

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Section 1
INTRODUCTION

BACKGROUND

Dare Food (Candy Division) Ltd. commissioned a candy manufacturing plant in Milton, Ontario in 1988. The candy product ingredients are mixed in mixing vessels and are then passed through a number of processing stages before moulding, setting, and drying. The processing plant has a high degree of automation, thereby minimizing water consumption. However, significant volumes of water are still required for cleaning and vessel and pipe washouts. The resultant wastewater has a very high BOD_5 due to the sugar and starch product ingredients. Dare Foods is presently discharging its processing shift wastewater directly to the Town of Milton's sanitary sewer system, while the more concentrated cleanup water is collected in a 10,000 Igal sump and hauled offsite on a weekly basis. Even though the major BOD_5 loading from cleanup is not discharged to the sewer, the wastewater leaving the Dare Food's property is still overstrength. As the Region of Milton is unlikely to permit surcharge payments for overstrength wastewater, due to the limited capacity of the Milton wastewater treatment plant, Dare Foods will have to implement a waste/wastewater management system in the near future.

In order to prepare for impending regulations that will require Dare Foods to comply with the Region of Halton's sewer use by-law limits for BOD_5 (300 mg/L) and TSS (350 mg/L), Dare Foods retained CH2M HILL to conduct a detailed characterization of their wastewaters and perform a preliminary investigation of potential wastewater treatment alternatives. The four waste treatment alternatives evaluated by CH2M HILL were aerobic biological treatment, anaerobic biological treatment, reverse osmosis (RO), and evaporation. CH2M HILL's report of August 1989, "The Evaluation of Wastewater Treatment Alternatives", concluded that reverse osmosis appeared to be the most attractive option. RO also had the potential benefit of recovering a marketable concentrated sugar solution from the wastewater. However, as there was very little information available on the use of RO for the treatment of candy manufacturing wastewater there was an element of risk in pursuing this treatment option. Therefore, it was strongly recommended that a pilot-scale testing of RO be performed to confirm the technical viability of the process and to determine important design criteria.

OBJECTIVES

The objectives of this report were to determine if RO treatment of the wastewater generated at the Dare Candy Milton Plant could:

1. Produce a high quality permeate capable of meeting the City of Milton's sanitary sewer discharge criteria for TSS (350 mg/L) and BOD_5 (300 mg/L). If pilot-tests were encouraging, CH2M HILL would establish operating parameters, preliminary design criteria, and an order of magnitude capital cost estimate for a full-scale plant.

2. Produce a concentrate of suitable quality to be marketable as an animal feed supplement.

Section 2
PILOT PLANT DESCRIPTION

PRINCIPLES OF REVERSE OSMOSIS

To facilitate understanding of the principle of reverse osmosis first consider natural osmosis. In Figure 2.1a. pure water is separated from a salt solution by a semi-permeable membrane through which water will pass. but dissolved salts cannot. Water flows through the membrane from the dilute solution to the more concentrated solution until the pressure generated by the osmotic head is equal to the osmotic pressure of the salt solution (see Figure 2.1b). When a pressure in excess of the natural osmotic pressure is applied to a solution in contact with a semi-permeable membrane. pure water will flow through the membrane. This phenomenon is called reverse osmosis (see Figure 2.1c).

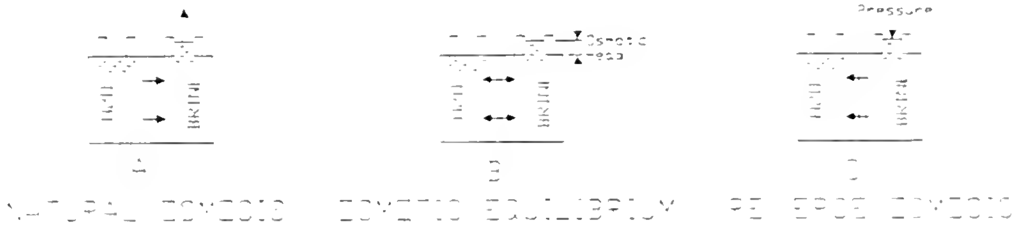

FIGURE 2.1 OSMOTIC PRESSURE

As well as removing dissolved salts from a solution. a reverse osmosis membrane is capable of removing bacteria. pyrogens and most organic materials such as the sugars and starches found in the wastewaters at Dare Candy, Milton.

The process is continuous. without the need for regeneration. and separates the feed into two streams. a relatively pure water stream (permeate) and a concentrate stream which contains the constituents of the feed in a more concentrated solution.

A reverse osmosis plant consists. essentially. of a high pressure pump. a membrane. and a pressure control device (see Figure 2.2). Operating pressures can range from 400 psig to 1200 psig.

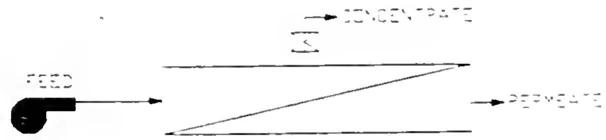

FIGURE 2.2 A GENERAL RO PLANT

PILOT PLANT LAYOUT

The pilot plant consists of the RO unit, wastewater tank, and connecting hoses (see Figure 2.3). The RO unit is a simple self-contained unit with 6.5 L hold-up volume, electric motor, Triplex pump, modules, heat exchanger, and controls, all mounted on a welded stainless steel framework (see Figure 2.4).

Process fluid is fed to the pump inlet, pressurized, and fed to the heat exchanger. Low pressure cooling water is fed through the stainless steel shroud of the heat exchanger using the hose spigots on the shell. This has the effect, if desired, of cooling the wastewater which, normally, heats up in the RO process. The process fluid then flows from the heat exchanger to the 18 - tube module (see figure 2.5). In the 18 - tube module the separation process takes place. The permeate passes through the semi-permeable membrane tubes into the stainless steel module shroud and is drained away via the hose spigots bonded to the shroud. The concentrate passes through the "tube side" of the module and is piped to the pressure control valve which maintains the operating pressure within the module.

Some test procedures require that the RO unit be operated as a total recycle system. In this mode the concentrate stream and permeate stream are fed back into the original feed tank. Operation of the pilot unit to simulate full scale treatment was in a batch mode which involves recycle of just the concentrate stream into the batch feed tank.

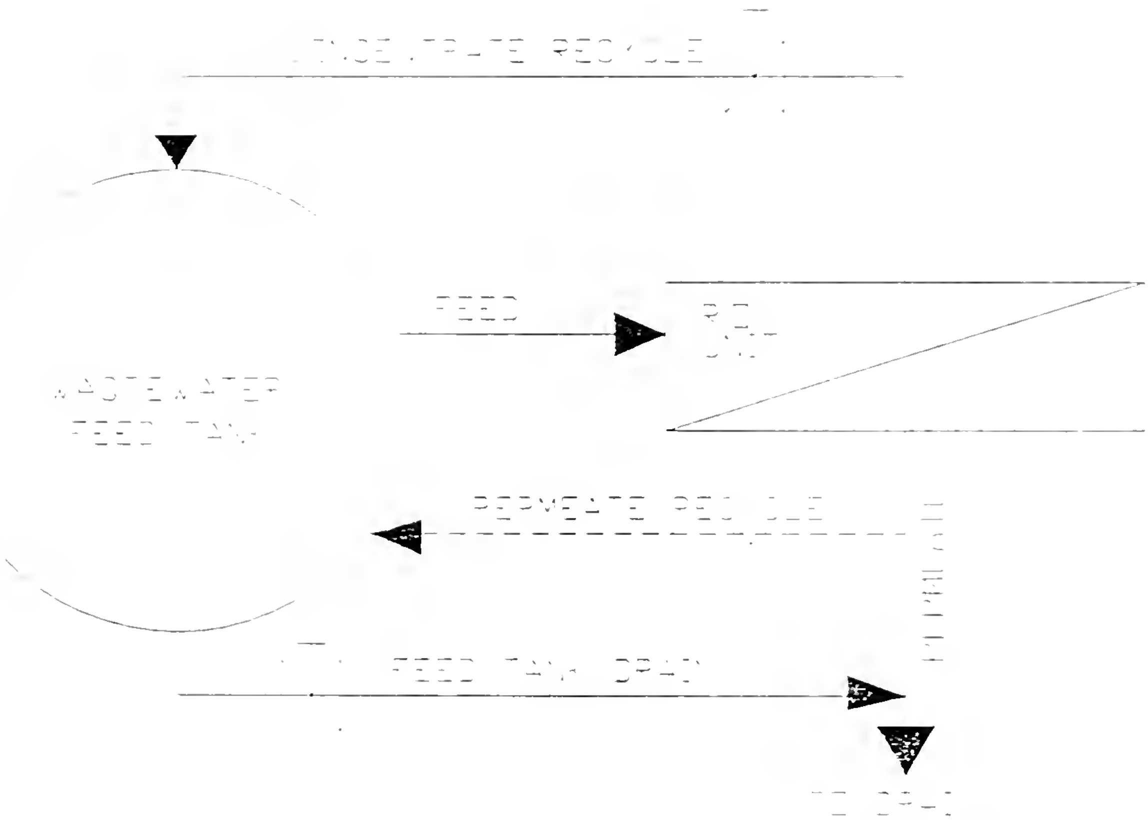

FIGURE 2.3: PILOT PLANT LAYOUT

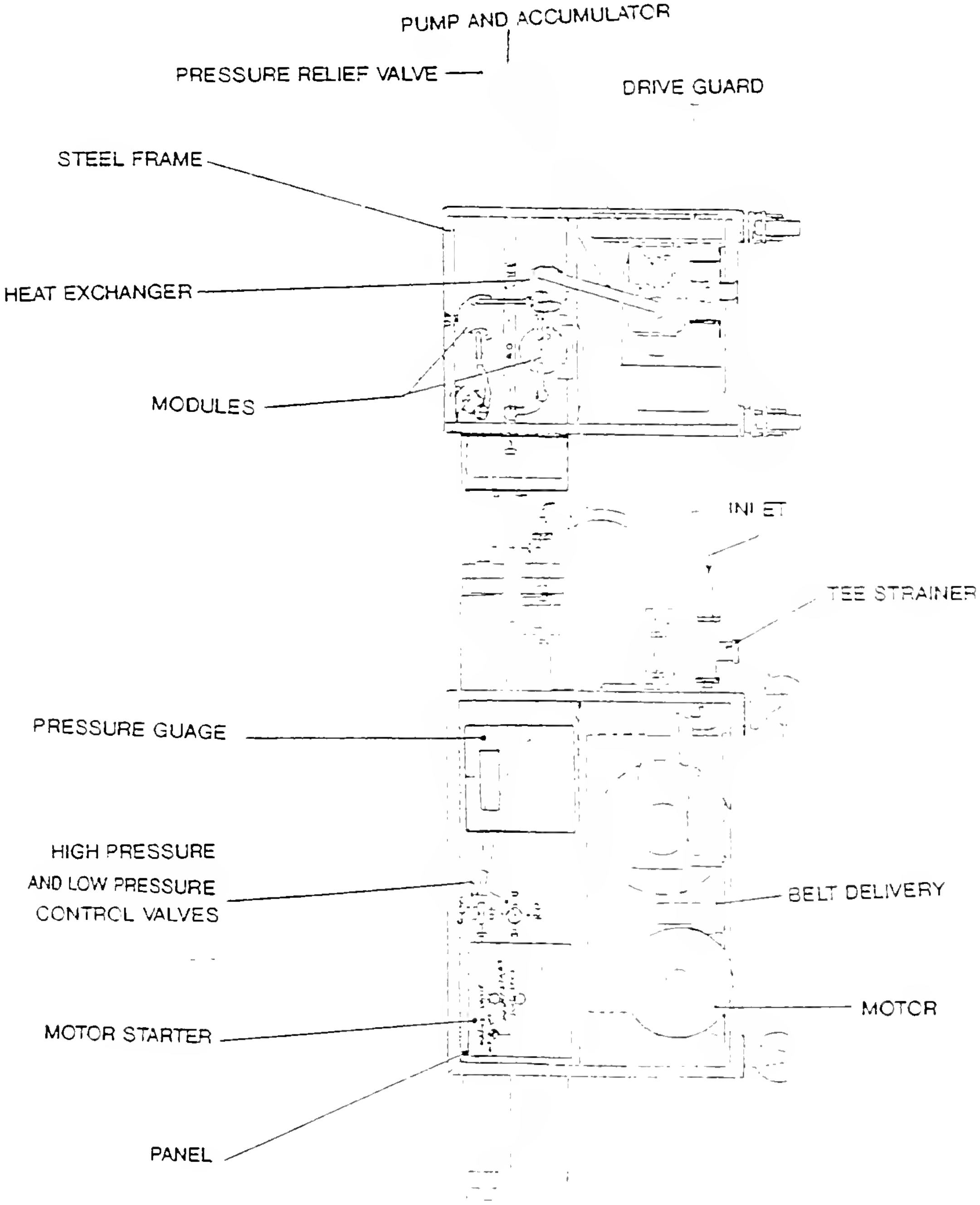

FIGURE 2.4: GENERAL ARRANGEMENT OF R.O. UNIT

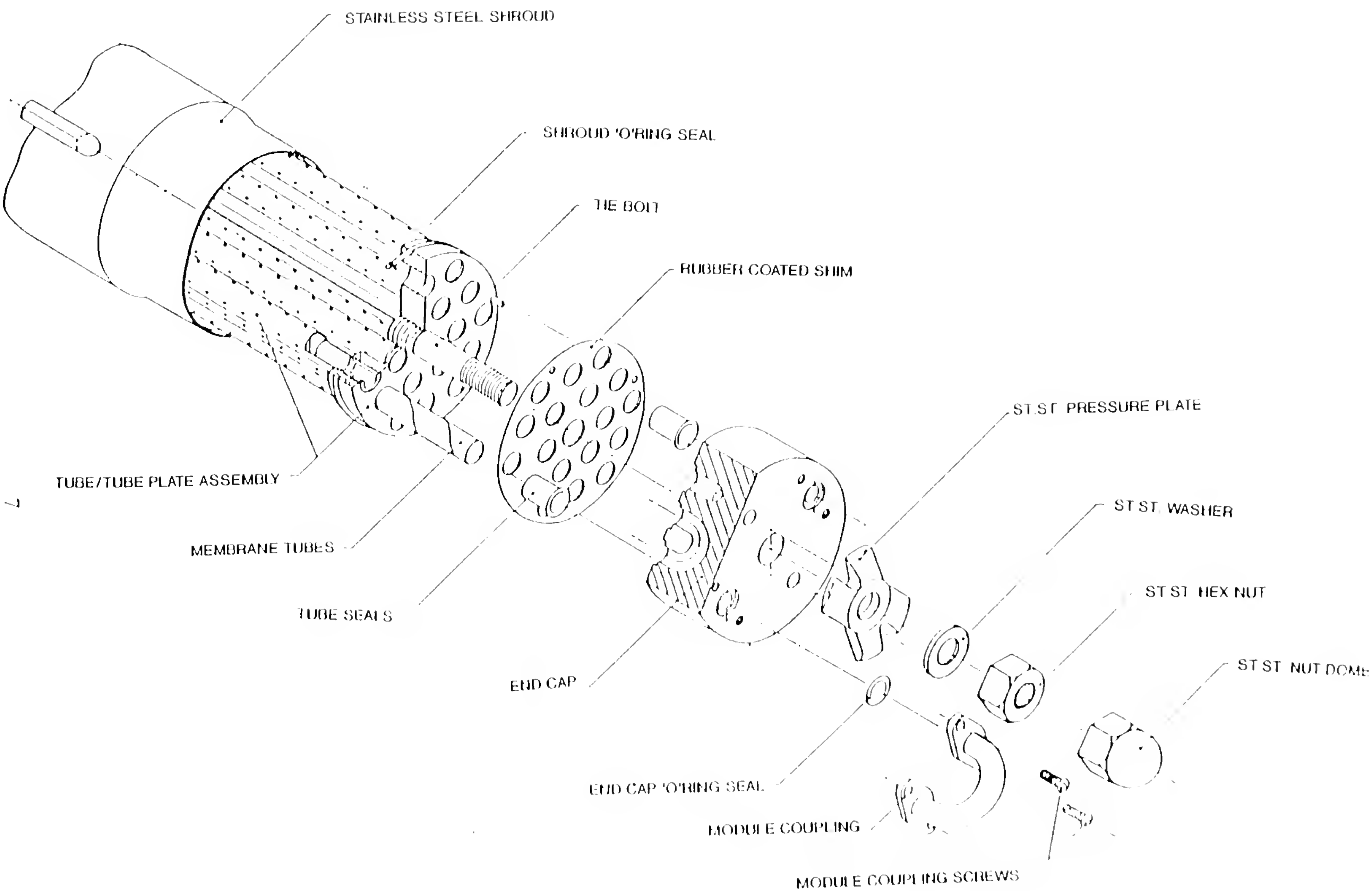

FIGURE 2.5: 18 TUBE R.O. MODULE

Section 3
TEST PROCEDURES

There are essentially 4 tests that can be performed to determine the operating characteristics of the RO membranes. These tests are as follows:

1. Initial check on the effect of operating pressure.
2. Relationship of Flux vs Concentration Factor.
3. Cleaning performance, and
4. Longer term running.

INITIAL CHECK ON EFFECT OF OPERATING PRESSURE

The purpose of this test is to discover if the wastewater will foul the membrane and if so to determine what operating pressure minimizes fouling. To do this the plant was operated on total recycle for 30 min at 400 psi then the flux was measured. Flux is the measured flow rate per unit area of membrane. The pressure was increased to 500 psi and after 10 minutes the flux was again measured. This process was repeated for 600 psi and 700 psi and then the pressure was reduced back to 400 psi in an identical stepped manner, measuring the flux on each occasion.

This plot should conform to one of the two general patterns shown in Figure 3.1.

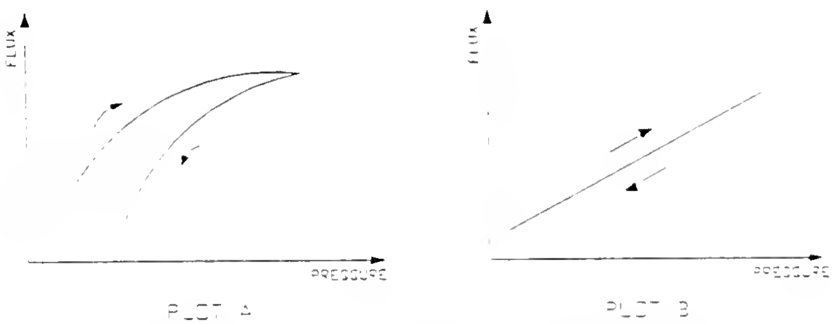

FIGURE 3.1: TYPICAL PRESSURE TEST CURVES

Plot A

This indicates that fouling or concentration polarization may be occurring at higher pressures and the subsequent tests should be performed at the pressure at which the flux was levelling out (although higher pressures may be usable at higher concentrations). If this occurs it could be worthwhile to carry out further tests on the effect of operating pressure.

Plot B

This plot indicates that increases in pressure are not required to maintain the flux rate and thus significant fouling does not appear to be occurring.

Actual results for these tests are discussed in Section 4.

RELATIONSHIP OF FLUX vs CONCENTRATION FACTOR

This test will determine to what concentration the wastewater can be concentrated before the flux rate declines to the point that treatment is uneconomical. For this test the pilot plant was run in batch mode with a constant feed temperature. Flux, conductivity, and pH were measured every 1 or 2 hours.

VOLUMETRIC CONCENTRATION FACTORS (VCF)

The feed tank volume was measured periodically to determine the volume processed and the degree of concentration of the fluid. Flux vs the volumetric concentration factor (VCF) were plotted (see Figure 3.2), where the VCF was determined as follows:

$$\text{VCF (at time t)} = \frac{\text{starting volume} + \text{plant hold-up volume}}{\text{vol at time t} + \text{plant hold-up volume}}$$

The plant hold-up volume is the approximate amount of fluid within the R.O. tubes. APV Canada Inc. estimates this to 6.5 L for the pilot plant used.

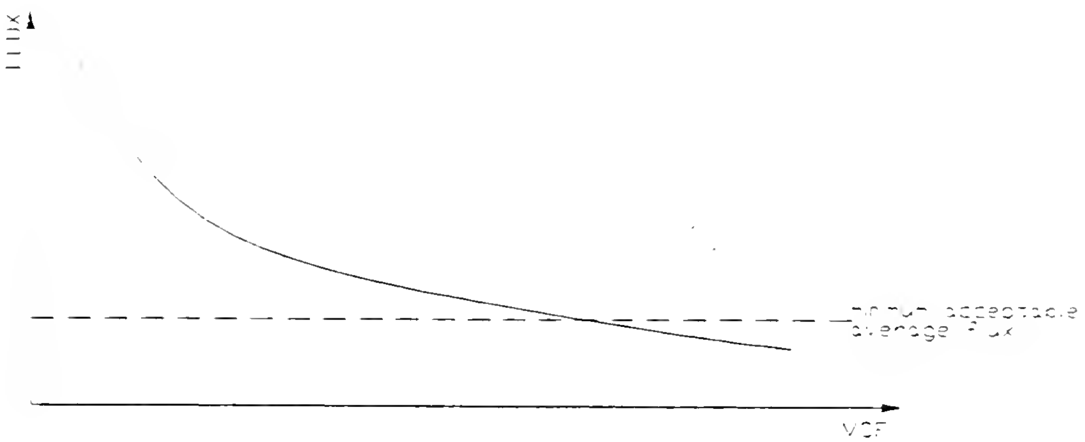

FIGURE 3.2: FLUX vs VOLUMETRIC CONCENTRATION FACTORS

CONTAMINANT CONCENTRATION FACTORS (CFF)

The feed, initial permeate, bulk permeate, final permeate, and final concentrate were sampled and analyzed for Oil and Grease, total solids, BOD_5, and conductivity. In addition the feed and final concentrate were analyzed for total sugars, monosaccharides, and disaccharides. Analysis of the permeate makes it possible to determine if the effluent can meet the City of Milton's Model Sewer Use By-Law criteria. Analysis of the concentrate provides the information necessary to assess the marketability of the final concentrate. Comparison of the initial feed to the final concentrate allows an estimation of the degree of concentration of the individual contaminants during the treatment process. The contaminant concentration factors were calculated as follows:

$$CCF = \frac{\text{Final Contaminant Concentration}}{\text{Initial Contaminant Concentration}}$$

CLEANING

Successful cleaning should lead to nearly full recovery of initial flux rates. However, over time there will likely be a gradual decrease in flux due to non-ideal cleaning. This results in flux curves as shown in Figures 3.3 and 3.4. Appropriate cleaning procedures and chemicals for the AFC 99 membrane were recommended by Diversey. Table 3.1 is a summary of the recommended cleaning processes.

LONGER TERM RUNNING

To determine the probable membrane life it is necessary to determine the relationship between the average flux per run and time. Figure 3.3 shows a typical Flux vs Time curve for an individual test run which can be used to determine at what point in time the membranes are likely to give unacceptable fluxes, as defined in Section 3 - Volumetric Concentration Factors (VCF), and therefore require cleaning (eg. Point A in Figure 3.3). The average flux (Point B in Figure 3.3) is the flux rate at the point in time where the CCF equals 2. A series of such curves (Figure 3.4) can show membrane recovery resulting from the cleaning process. A line joining the average flux points on these individual curves can possibly be used to estimate membrane life.

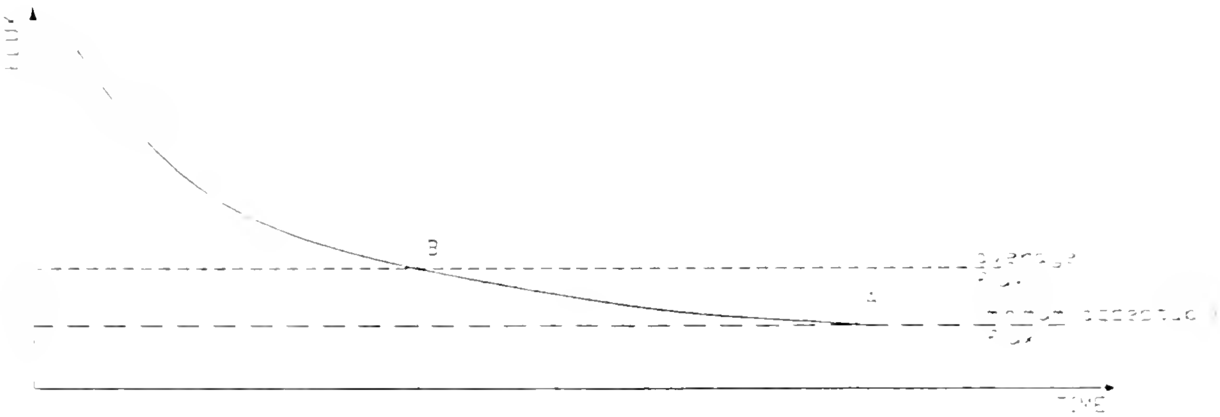

FIGURE 3.3 FLUX vs TIME FOR AN
INDIVIDUAL TEST RUN

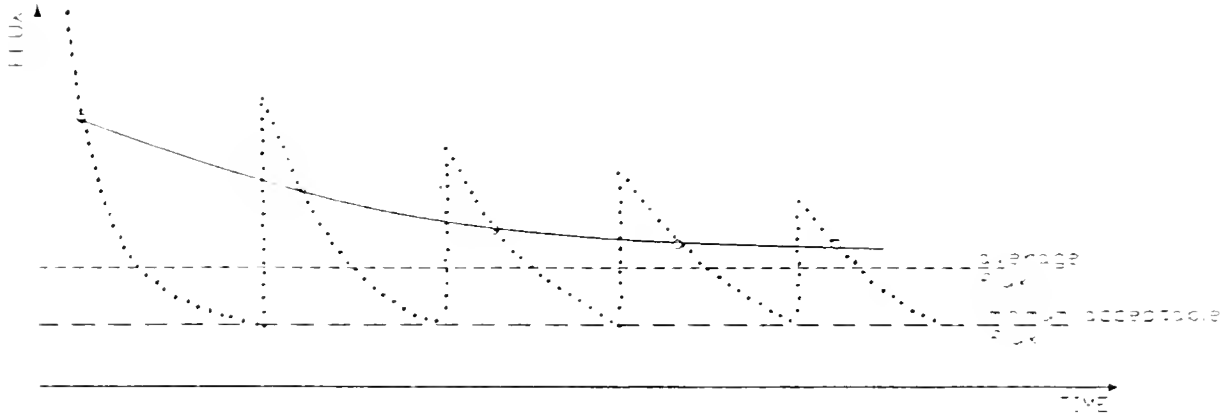

FIGURE 3.4 A SERIES OF FLUX vs TIME CURVES
WITH THE AVERAGE FLUXES JOINED
BY A CURVE

TABLE 3.1: DIVERSEY'S RECOMMENDED CLEANING PROCEDURE

STEP	DESCRIPTION	PRODUCT	CONCENTRATION	TARGET pH	TIME	TEMPERATURE	COMMENTS
1	Potable rinse water (chlorine free)				10-15min	Ambient, warm preferred	
2	Acid wash	DIVOS 2	0.5% wt/wt or 0.49% gal/100gal water	2 - 3	30 min	100 F	Add product slowly over a 5 min period. Measure pH 5 min after final addition
3	Potable rinse water (chlorine free)				10 min	Ambient	
4	Built alkali wash	DIVOS 1 FRP	0.75-1.0 wt/wt or 0.65-0.85 gal/100gal water	12.0	40 min	110 F	Add product slowly over a 10 min period. Measure pH 5 min after final addition
5	Potable rinse water (chlorine free)				10 min	Ambient	
6	Storage	DIVOS Soak	0.1% wt/wt or 0.8 lbs/100 gal water	[illegible]	Soak for a minimum of 5 hrs, 2 or 3 times a week	Ambient	For longer than 48hr shutdown a conc. of 0.2% wt/wt should be used.

Section 4
DISCUSSION OF RESULTS

GENERAL

Dare Candy, Milton produces a wide variety of products, therefore a variety of wastewaters were collected to gain an understanding of the membranes' response to different feed conditions. Wastewaters tested during this study were generated from the production of general gum and mallow products, jube-jubes, jelly bean centres, and Gummi Bears. Wastewater was collected over the processing and cleanup shifts combined, to simulate the scenario where all wastewaters are diverted for treatment. In addition just the cleanup shift wastewaters were collected to simulate the scenario where the process shift is treated separately or is released to the sewer and the cleanup wastewater is retained for RO treatment. These wastewaters were run through the RO pilot plant in a batch concentration mode. Samples were taken from the initial feed to determine starting conditions; from the initial permeate, bulk permeate, and final permeate to evaluate the quality for discharge to the municipal sanitary sewer; and from the final concentrate to evaluate the market value for future resale. In two separate instances, samples were made from the bulk concentrate and the settled concentrate to evaluate the market value of these two alternative forms of wastewater concentrate. The analytical data from all test runs are presented in Table 4.1.

Certain mechanical operating problems were experienced with the pilot plant. The lack of accurate controls on the pilot plant led to fluctuations in both the pressure and temperature. Additionally there appeared to be occasional air locks in the permeate lines. All of these factors resulted in apparent wide fluctuations in flux rates.

The final concentrate varied depending on initial wastewater conditions. In general, the wastewater was a thick syrupy liquid with a pH of approximately 5. The concentrate from the Gummi Bear wastewater had a similar pH to the other wastewaters, but it congealed at room temperature.

OPERATING DATA

CONCENTRATION

The volumetric concentration factors (VCFs) were calculated, but since some solute passes through the membrane, this estimation of the concentration factor was considered to be somewhat high. A comparison of contaminant concentration factors (CCFs) calculated from measured conductivities, total solids (TS), oil and grease (O&G), and BOD_5 in the feed and concentrate was made (see Section 3.2.2). It is not theoretically possible for suspended solids to pass through an RO membrane, therefore TS analysis on permeate samples represents the Total Dissolved Solids (TDS). This

Table 4.1
Analytical Results for RO Pilot Study

Lot #	Date	Sample Location	Conductivity (umhos/cm)	Total Solids (mg/L)	Oil & Grease (mg/L)	CBOD (mg/L)	Total Sugars (%)	Mono-saccharide (%)	Di-saccharide (%)	Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Iron (mg/L)
5112 TEST 2	Sept. 18	Init. Feed	702	29000	18	219000				24.3	8.25	84.2	2
		Init. Permeate	37		2.8	41							
		Bulk Permeate	87		3.1	550							
		Final Permeate	321		1.8	5120							
		Bulk Conc.	2110	113000	233	204000							
		Final Conc.	2510	382000	211	659000	(35.4)	1	21.4				
5414 TEST 4	Sept. 19	Init. Feed	801	15360	1	33000				31.7	12.5	97.2	4.85
		Init. Permeate	31		2.6	110							
		Bulk Permeate	339		602	850							
		Final Permeate	157		1.9	2170							
		Final Conc.	1900	388110	589	691000	(33.2)	(0.1)	17.7				
5453 TEST 5	Sept. 21	Init. Feed	1600	122000	72	68900				22	5.81	58	2.56
		Init. Permeate	215		<1	91							
		Final Conc.	1240	225000	61	180000	(22)	0.1	12				
5471 TEST 6	Sept. 23	Init. Feed	930	96200	28	60300							
		Init. Permeate	51		<1	120							
		Bulk Permeate	71		<1	196							
		Final Permeate	130		2.3	576							
		Final Conc.	1350	319000	37	216000	(27.1)	0.5	14.6				
5490 TEST 8	Sept. 26	Init. Feed	1378	15300	19	13190		0.2	5.8				
		Init. Permeate	35		<1	54							
		Bulk Permeate	1160		1	240							
		Final Permeate	2290		1.6	630							
		Final Conc.	7130	11500	283	96900		0.5	11				
5512 TEST 9	Sept. 28	Init. Feed	614	62100	51	51010							
		Init. Permeate	53		5.8	38							
		Bulk Permeate	32		6	900							
		Final Permeate	136		4.5	2150							
		Final Conc.	1153	351000	86	317800		0.6	22.6				
5513 TEST 10	Oct. 01	Init. Feed	816	13300	21.8	*							
		Init. Permeate	38		7.2	82							
		Bulk Permeate	70		3.8	280							
		Final Permeate	126		6.8	690							
		Final Conc.	1980	150000	133	1070350		0.3	7.6				
		Settled Conc.						0.3	7.7				
5702 TEST 14	Oct. 22	Init. Feed		11900		33100	(39)	0	2				
		Init. Permeate											
		Bulk Permeate				1070							
		Final Permeate				3100							
		Final Conc.		251000		165000	(21.5)	0.6	10.2				
5721 TEST 16		Init. Feed		95800		26110	(3.6)	0.3	1.9				
		Init. Permeate				61							
		Bulk Permeate				630							
		Final Permeate				4870							
		Final Conc.		25157		290000	(28)	1	10.7				
5721 TEST 18		Init. Feed		22100		19200	(2)	0	0.9				
		Init. Permeate				140							
		Bulk Permeate				200							
		Final Permeate				670							
		Final Conc.		189000		366000	(17.3)	0.9	8				

* Erratic Results

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comparison revealed that the TS concentration factors demonstrated the best consistency and comparability to the volumetric concentration factors, although generally with smaller values and a little more variability. Therefore, although the VCF was probably a high estimation of the actual concentration factor, it was used for all calculations due to its apparent relative consistency.

Degrees Brix is a standard unit for reporting sugar concentration. A degree Brix is equivalent to a concentration of one percent cane sugar. A relationship between the Degrees Brix of the final concentrate to the final VCF was used to estimate the intermediate Brix concentrations. This relationship was used to produce Brix vs Time plots (Figures 4.1 and 4.2) for each run. Figure 4.1 shows the change in Brix with time for all runs using the first set of membranes. Figure 4.2 demonstrates the Brix over time for the new set of membranes. It is apparent that even with various feed waters, on average, a Brix value between 20 and 30 can be achieved within 24 hours.

The volume reduction and VCF achieved for each test run are listed in Table 4.2. Also included in Table 4.2, are the final concentrate Brix concentrations to indicate that similar Brix concentrations were achieved at widely varying VCFs. Concentrating Dare's wastewater in the RO unit resulted in an average reduction in wastewater volume of 86.7 percent. If 15,000 gallons per day of wastewater were treated, 2000 gallons of concentrate would require disposal. Wastewater for test number 5 appeared significantly different from any other wastewaters tested. The pilot plant shut down for two long periods (greater than 3 hours) during the treatment of this wastewater which appear to adversely affect the membranes for tests 5 and 6. If these tests are excluded from the study, the average volume reduced achieved was 92.2 percent.

FIGURE 4.1: DEGREES BRIX vs TIME
(FOR OLD MEMBRANES)

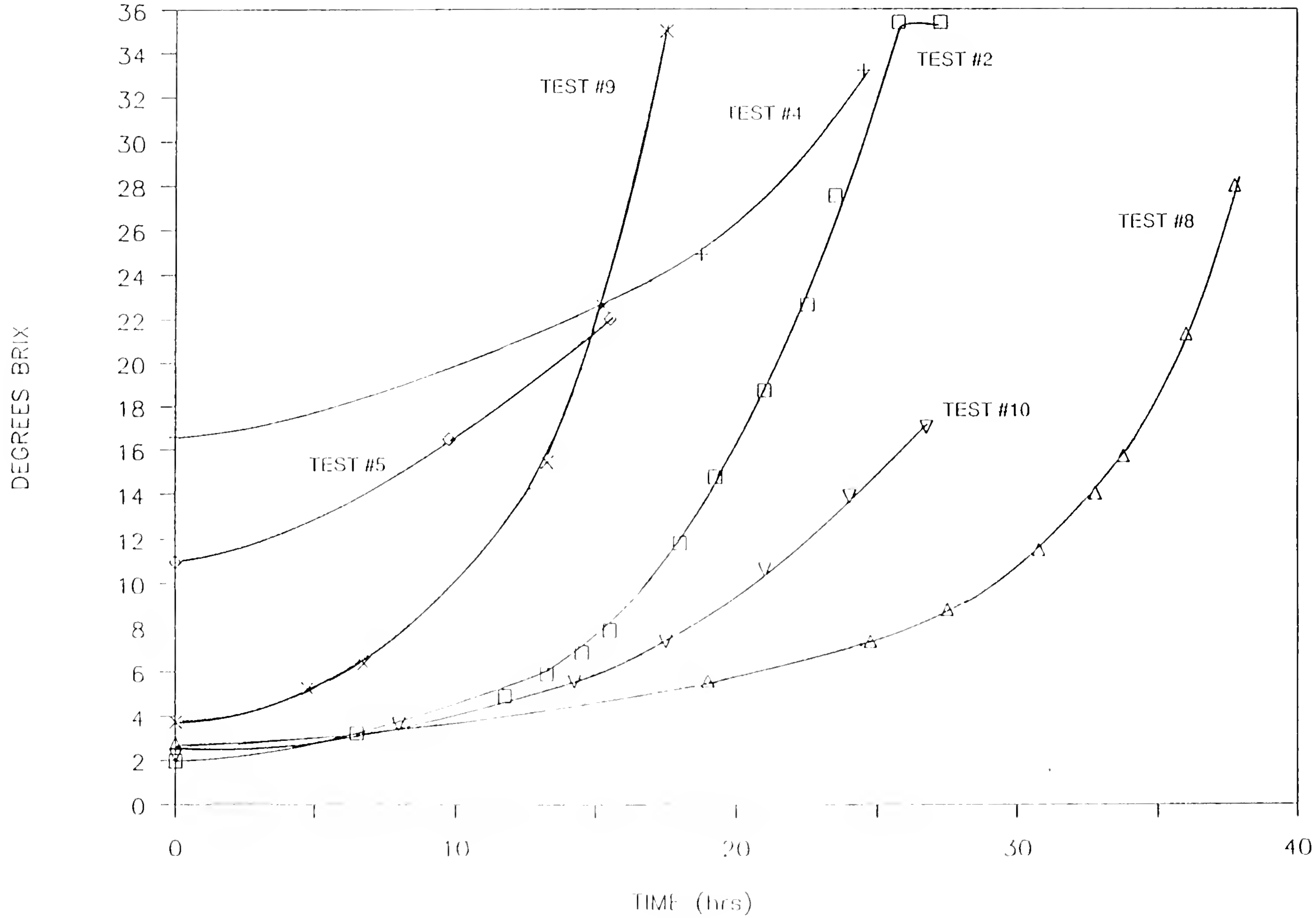


FIGURE 4.2: DEGREES BRIX vs TIME

(FOR NEW MEMBRANES)

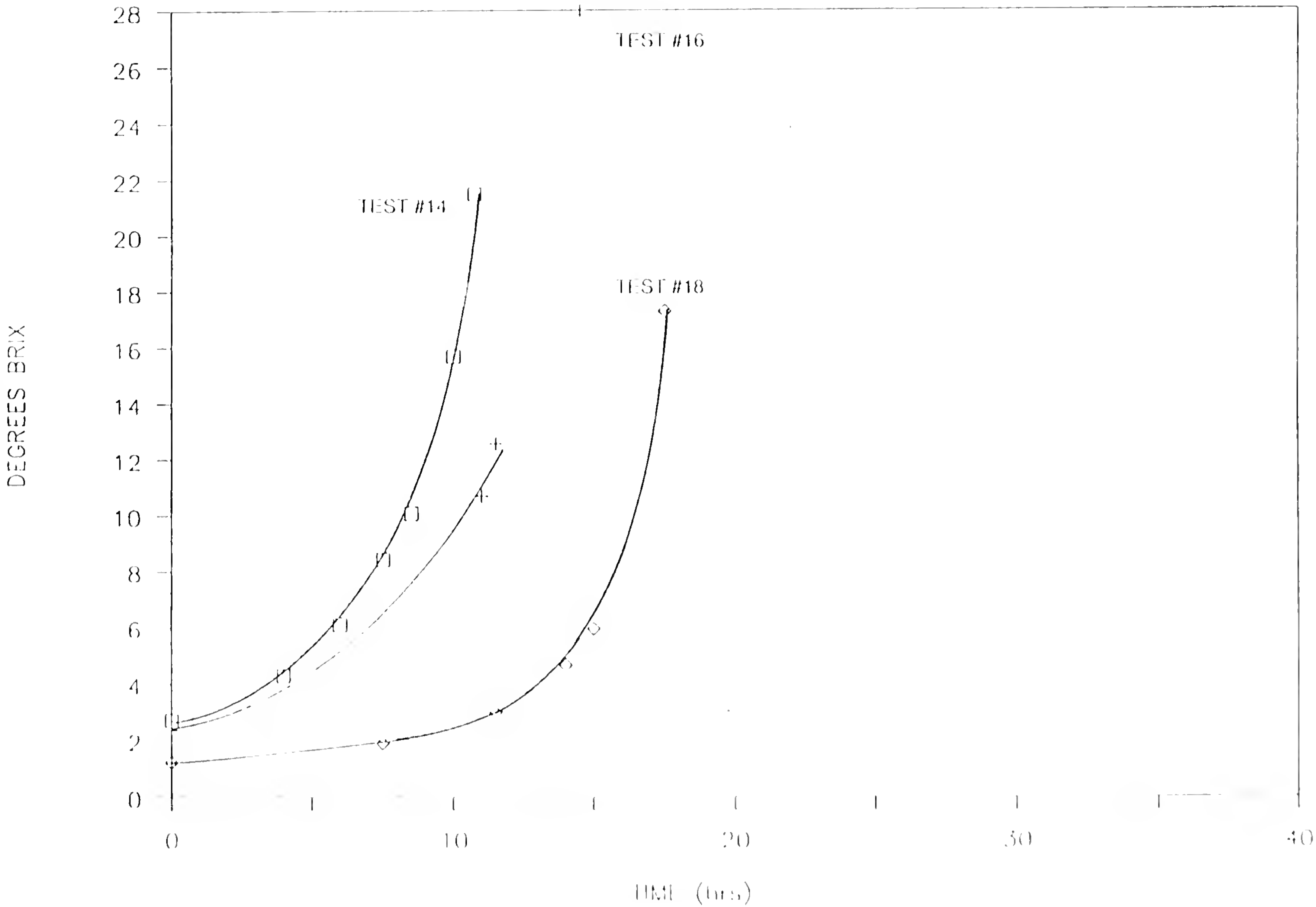


Table 4.2 Wastewater Volume Reduction					
Test Number	Volume			VCF	°Brix Final Concentrate
	Initial (L)	Final (C)	% Reduction		
2	800	37	95.0	10.0	35.4
4	800	20	97.5	30.4	33.2
5	825	325	60.6	2.5	22.0
6	825	255	69.1	3.2	27.1
8	800	75	90.6	10.0	
9	425	40	90.6	90.3	
10	500	60	88.0	7.6	
14	400	45	88.8	7.9	21.5
16	425	30	92.9	11.8	28.0
18	425	25	94.1	13.7	17.3
Average	-	-	86.7	11.4	26.3

$$V.C.F. = \frac{Vinit + 6.5}{Vfinal + 6.5}\text{; Plant holdup Volume} = 6.5\ L$$

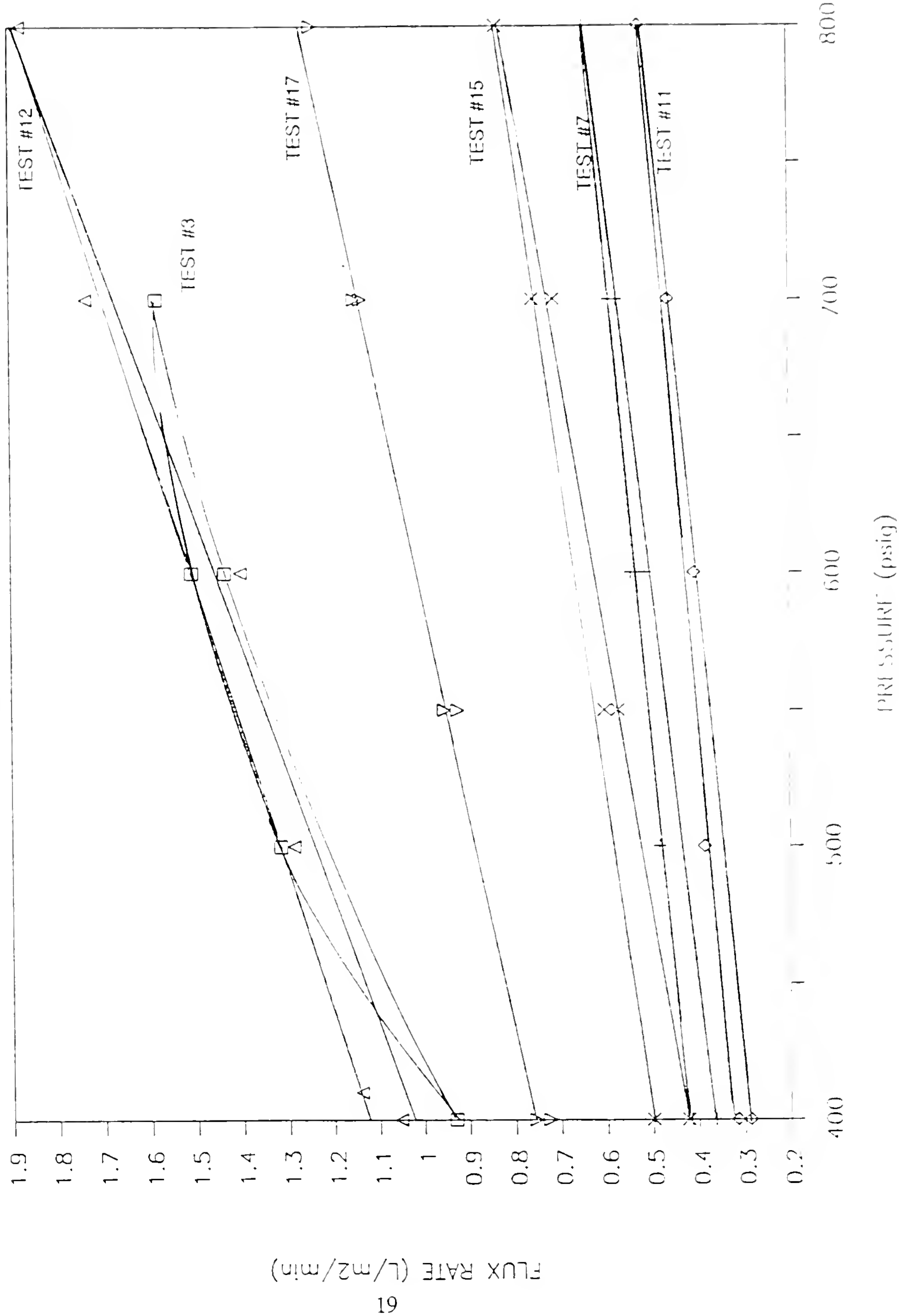
FLUX RATES

It is possible to standardize the flux to eliminate the effects due to temperature variations, but due to changes in osmotic pressure which can not be calculated from the data, it is not possible to standardize for pressure. Therefore, all flux rates were standardized to a temperature of 35°C.

Using the data, standardized as described above, it can be seen from Figure 4.3 that the chlorine free potable water pressure tests did not exhibit any significant fouling. Only test #3 demonstrated potential fouling, but if an allowance of +/- 0.05 L/m^2/min (due to minor pressure fluctuations and air locks in the permeate line) is used, test #3 also demonstrates no significant fouling. Pressure tests on the wastewaters (Figure 4.4) showed that the mallow wastewaters may lead to fouling of the membrane if operated at pressures greater than 600 to 650 psig for the temperature tested. Operation at higher temperatures may allow for treatment at higher pressures, but solute passage through the membrane may also increase. Jube-jube wastewaters demonstrated no

FIGURE 4.3: FLUX VS PRESSURE TEST

FOR POTABLE WATER (T=35 C)



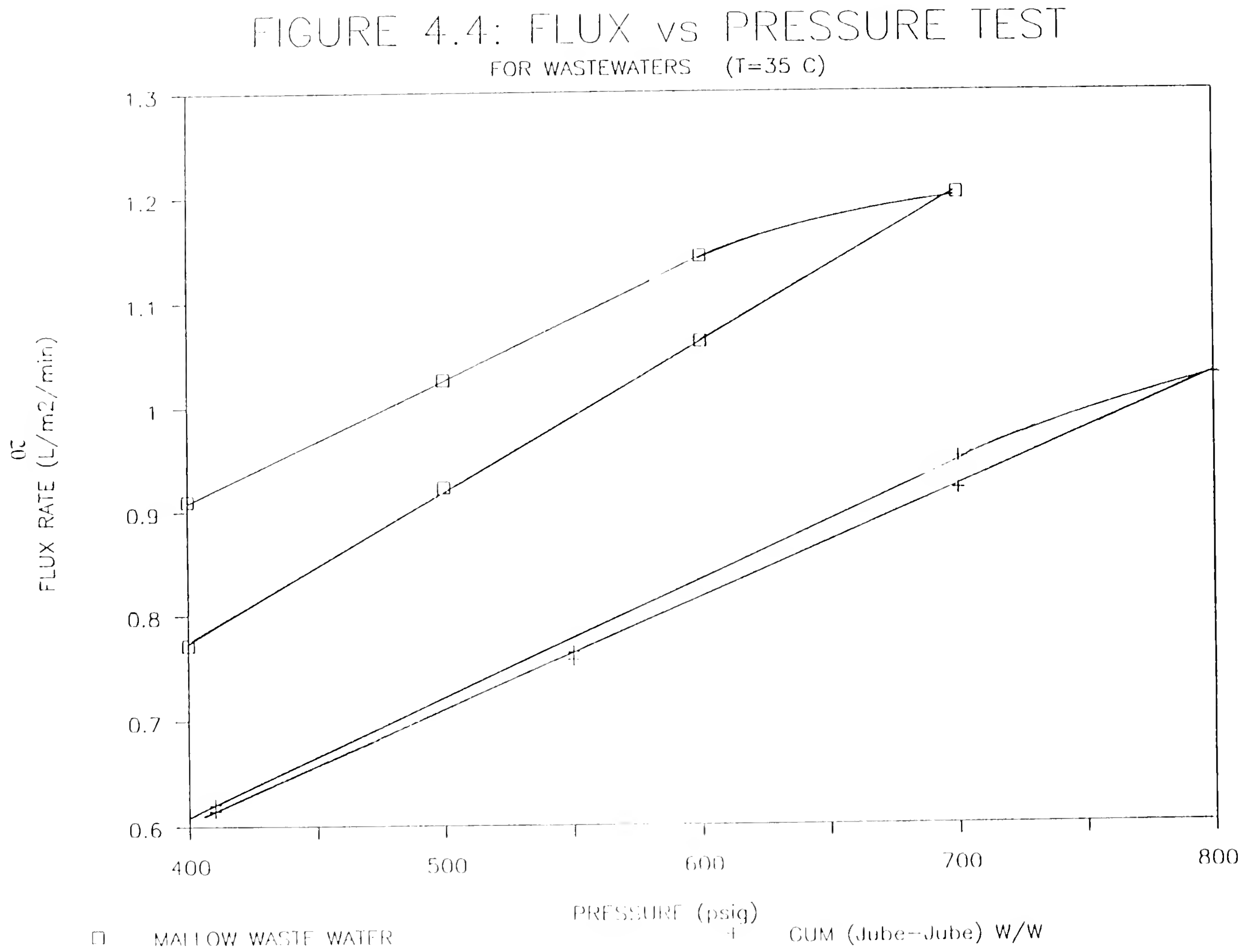


FIGURE 4.4: FLUX vs PRESSURE TEST
FOR WASTEWATERS (T=35 C)
FLUX RATE (L/m2/min)
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
400
500
600
700
800
PRESSURE (psig)
MALLOW WASTE WATER
GUM (Jube-Jube) W/W

significant fouling up to the test limit of 800 psig and since the general gum wastewaters were similar in analysis, consistency (specific gravities of raw gum wastewaters were approximately 20 while the specific gravity of raw jube-jube wastewater was approximately 15), and appearance to the jube-jube wastewater, it is assumed that it will have similar fouling characteristics. The specific fouling characteristics of jellybean centre wastewaters and the Gummi Bear wastewaters are unknown. Jellybean centre wastewaters caused wide fluctuations in the pressure and lead to automatic shutdowns of the pilot plant when the pressure would rise suddenly to the upper set point of 845 psig. These fluctuations were likely due to plugging of the pressure control valve which may be attributable to debris in the wastewater or the grainy nature of jellybean centre wastewaters.

Figures 4.5 and 4.6 show the flux rates versus time for the old and new membranes used during the test. These have been included to indicate the flux decline which occurs with time and VCF. Pressure fluctuations and plant shutdowns make it difficult to determine an average flux for the old membranes. Three tests were performed using the new set of membranes and the lowest average flux was 29 L/m^2hr for the last test. The minimum acceptable average flux for design purposes which was set prior to testing, was 20 $L/m^2/hr$. Therefore, flux rates maintained during testing were acceptable but long term projected flux rates were questionable. This topic is discussed in Section 4 - Membrane Life.

A comparison of potable water pressure tests performed 7 times during operation of the pilot plant indicated a variation in the initial flux rates of each run. These tests did not indicate that irreversible fouling of the membrane was occurring or that there was inadequate cleaning of the membranes.

SOLUTE REJECTION

Solute rejection by the RO membrane was able to reduce the BOD_5 concentration in the wastewater by an average of 99.4 percent. Rejection of sugars by the RO membrane was projected to be greater than 97 percent during the evaluation of treatment alternatives. Rejection during the operation of the pilot plant was based on feed and permeate conductivities. An average of 95.9 percent rejection of solutes was observed throughout the pilot study. This lower rejection probably resulted in the bulk permeate concentrations being in excess of the sanitary sewer by-law limit of 300 mg/L for 6 out of 10 tests.

CLEANING PERFORMANCE

In order to efficiently process the wastewater collected for the pilot study the temperatures used for cleaning were at the lower end of the recommended ranges since heating of the solutions was very time consuming. The poor flux recoveries exhibited by the first set of membranes (Figure 4.5) may have resulted from these conditions.

FIGURE 4.5: FLUX vs TIME

FOR OLD MEMBRANES (35C)

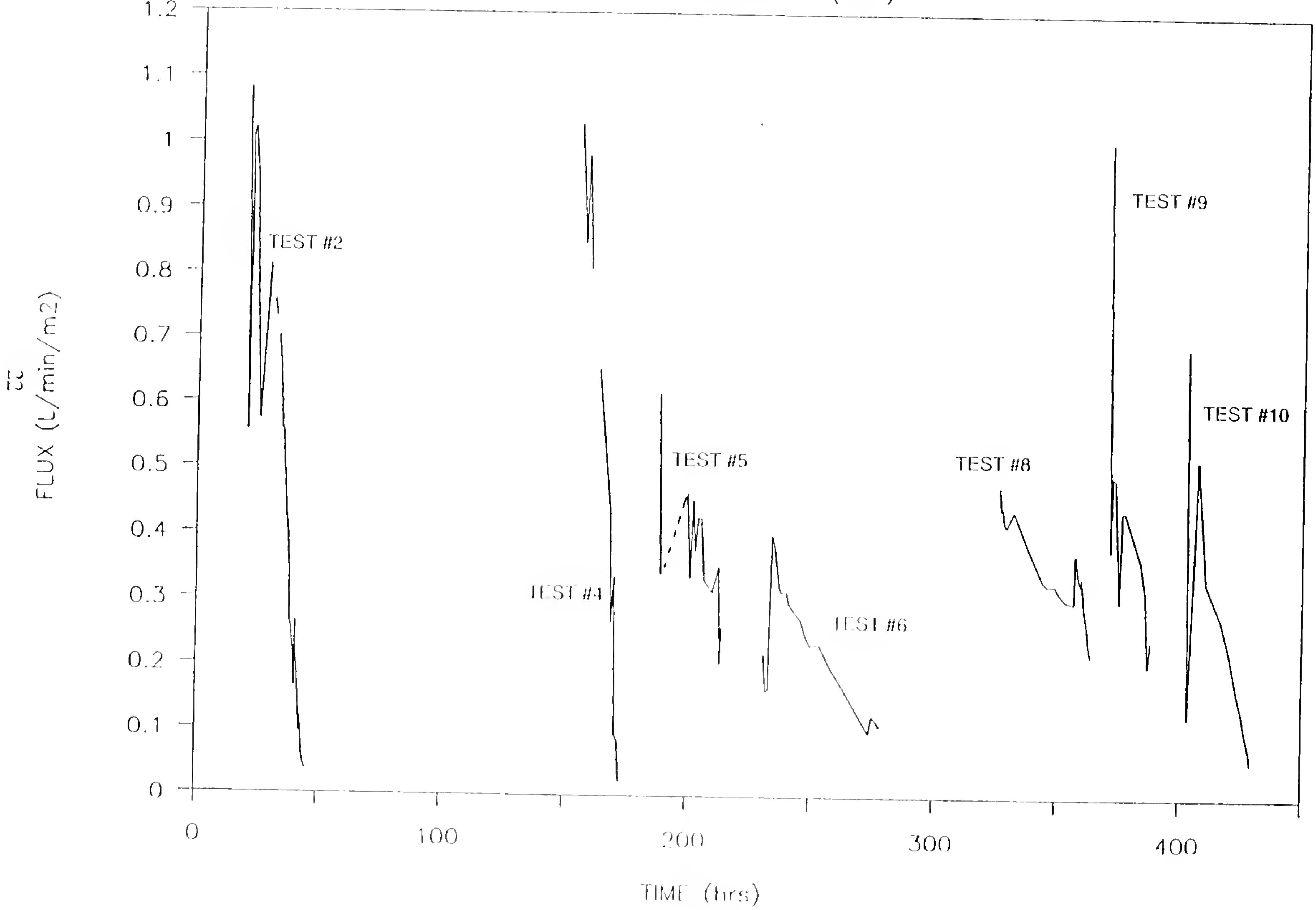


FIGURE 4.6: FLUX vs TIME

FOR NEW MEMBRANES (35C)

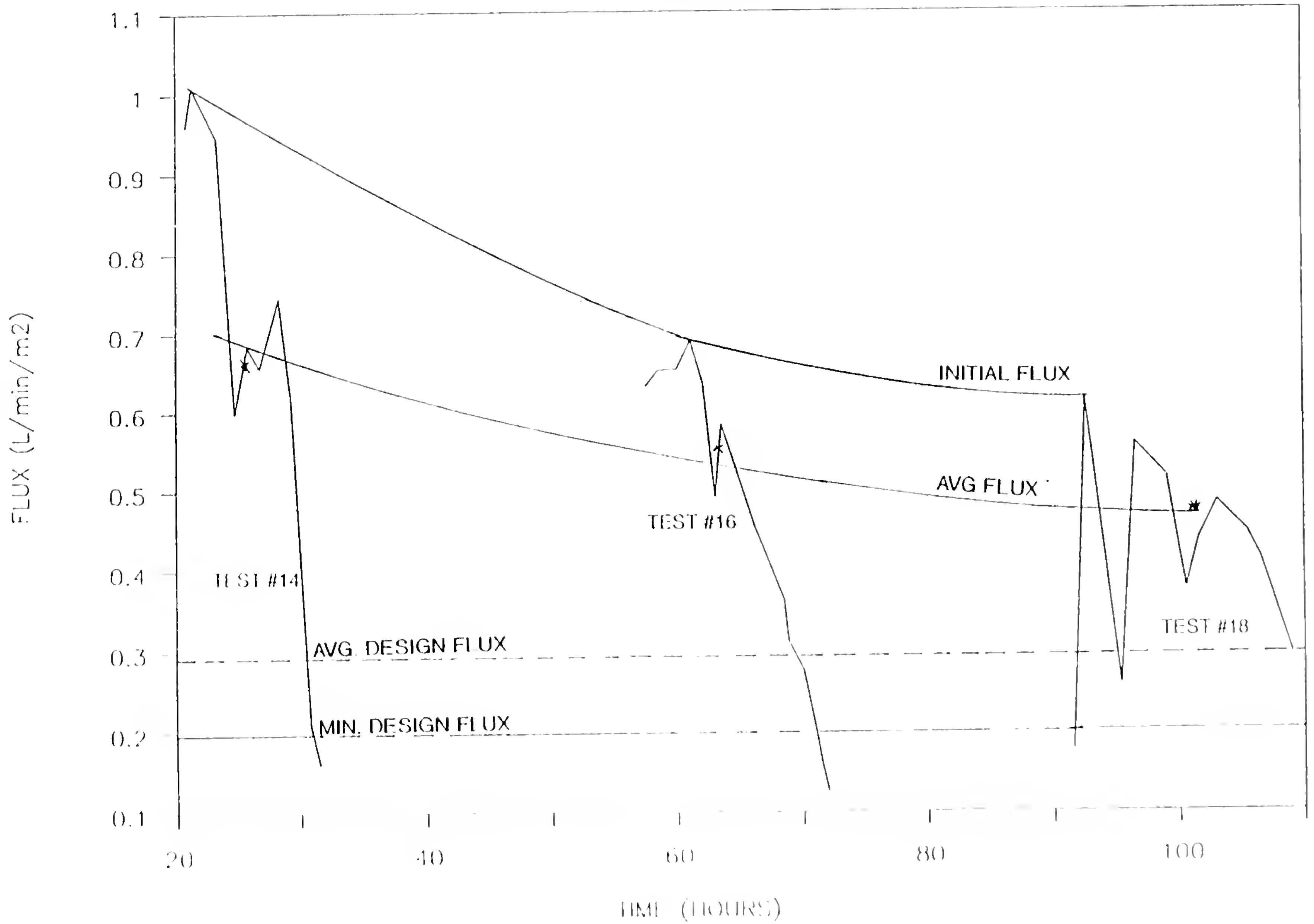


Figure 4.6 shows the flux recovery after cleaning the new set of membranes using higher temperatures. The result indicates a more even flux decline than that exhibited by the first set of membranes, as well as a gradual levelling off of the flux decline.

It should be noted that long periods of soaking the membranes in the DIVOS soak solution greatly increased the recovery in flux rates.

MEMBRANE LIFE

Due to the variability of pressures and two prolonged automatic shut-downs of the pilot plant (ie. of 5 hours or more), the first set of test runs using the original membranes cannot be used to accurately predict membrane life. Instead these runs indicate how the membranes react to different pressures, temperatures, and wastewaters. Figure 4.5 shows a gradual decrease in flux rates over time with a marked increase in the flux rate for every pressure increase.

The set of test runs with the new membranes may be used to try to estimate membrane life, but based on the limited pilot-testing with these membranes there would be very little confidence in any projections. Using average flux rates from the tests with the new membranes along with the apparent decline in the initial flux rates after each cleaning event (as shown on Figure 4.6) membrane life before replacement is required could range from 2 to 12 months or longer.

ANALYTICAL RESULTS

DISCHARGE CRITERIA

To meet the City of Milton's sanitary sewer discharge criteria it is necessary for the permeate to have a pH between 6.0 and 10.5, BOD_5 concentration less than 300 mg/L, TSS concentration less than 350 mg/L, and Oil and Grease concentrations less than 100 mg/L. Table 4.7 summarizes the analysis for the initial, bulk, and final permeate for each test run and compares the concentrations to the model sewer use by-law limits.

The analytical results for the initial, bulk, and final permeate demonstrate the dramatic increase in contaminant concentration in the permeate near the end of the concentration process. It is possible that this increase is exponential and therefore the high contaminant concentration in the bulk permeate is probably primarily due to the latter portion of the concentration process. Therefore to limit the contaminant concentration in the bulk permeate (bulk BOD_5 exceeds the by-law limits in 6 of the 10 tests), it would be necessary to end the concentration process before the bulk permeate exceeds the by-law limits.

Table 4.7
Chemical Analysis of Permeate

Test Number	Wastewater Type	Average Feed pH	BOD_5 Concentration (mg/L)			Conductivity (µmhos/cm)		
			Initial	Bulk	Final	Initial	Bulk	Final
2	Mallow	4.6	44	550	5120	37	87	321
4	Gum	4.9	110	850	2170	34	339	157
5	Gum	4.8	94	-	-	215	-	-
6	Gum	3.8	120	196	526	54	74	130
8	Gum	4.6	54	260	630	45	1160	2220
9	Gum	4.7	38	900	2150	53	32	136
10	Mallow	5.7	82	280	620	38	70	126
14	Gum	4.8	-	1070	3400	-	-	-
16	Gum	4.7	61	630	3870	-	-	-
18	Gum	5.2	140	290	670	-	-	-
Model Sewer Use By-law		6.0-10.5	300	300	300	-	-	-

Since BOD_5 most frequently determines compliance for Dare Foods and since BOD_5 cannot be instrumentally determined, a relation between an instrumentally detectable parameter and BOD_5 needed to be established. It was observed that an exponential relation between BOD_5 and degrees Brix gave an 82 percent correlation for the wastewaters tested. Therefore online monitoring of degrees Brix may be a possible method for determining the relative BOD_5 levels of the permeate.

CONCENTRATE QUALITY

The marketability of the final concentrate is based on TS and degrees Brix. Table 4.8 indicates the variation in chemical analysis with different test runs. This information was presented to potential consumers who evaluated it and found that under present market conditions the best possibility for the concentrate was that it may be removed free of charge. There was agreement however that they could, indeed, make use of this concentrate.

Table 4.8
Variation in Chemical Analysis of Concentrate

Concentrated Wastewater Test #	Degrees Brix	Total Solids (mg/L)	Total Solids (%)
2	35.4	382,000	38.2
4	33.2	388,400	38.8
5	22	225,000	22.5
6	27.1	319,000	31.9
8	(25)	14,500	1.4
9	(35)	384,000	38.4
10	(17)	150,000	15.0
14	21.5	250,000	25.
16	28	25,157	2.5
18	17.3	182,000	18.2

Note: () indicates the approximate Brix as calculated from the monosaccharides and disaccharides

Section 5
CONCLUSIONS AND RECOMMENDATIONS

1. RO pilot plant tests were undertaken to confirm system design criteria and achievable permeate quality. Although the RO system was able to treat the Dare Candy wastewater to give a clear permeate with greatly reduced BOD_5 concentrations, a number of technical and design limitations were identified.

2. Initial permeate BOD_5 concentrations for each batch test were well below the Region of Halton's sanitary sewer use by-law limit of 300 mg/L. However, the bulk (average) permeate BOD_5 concentrations varied between 196 mg/L and 1070 mg/L, with 6 out of 10 test runs having bulk permeate BOD_5 concentrations in excess of the by-law limit. The average BOD_5 concentration reduction through RO treatment was greater than 99.4 percent. The solute rejection based on conductivity averaged 96 percent throughout the study.

3. The wastewater samples collected for the pilot study had higher measured sugar concentrations than expected based on the initial characterization study. This may be attributed to the fact that the production processes are running more consistently than during the plant startup which was when the initial characterization study was performed.

4. Two sets of membranes were evaluated during the pilot-test work. The initial membrane set supplied by the manufacturer arrived without preservative, casting some doubt on their condition. Therefore, a second set of membranes was ordered and tested and satisfactory average flux rates of approximately 30 $l/m^2 h$ were obtained for the 3 test runs performed.

5. An apparent decline in the initial flux rate after each cleaning event was observed throughout the study. Membrane life projections were difficult based on the limited pilot-testing, but relatively poor membrane life expectancies could be indicated by this apparent initial flux decline. Potable water pressure tests did not display the characteristics of irreversible fouling. Short membrane life expectancies would greatly increase the RO system operating costs projected in CH2M HILL's August 1989 evaluation report which were based on a 12 - 18 month membrane life.

6. The RO system was capable of consistently concentrating the wastewater to the targeted 20 percent sugar (20°Brix) concentration level.

7. Concentrate disposal was investigated and although a number of farms were interested in the material, under the present market conditions it would not be expected to have much monetary value. At best, the farms indicated that the material could be removed from the site free of charge. The long-term reliability of this method of disposal is unclear and could result in some risk.

Section 6
RECOMMENDATIONS

The pilot-testing showed that there are technical limitations in implementing an RO system to treat the combined Dare Foods candy wastewater flow, which includes the high strength cleanup waters and normal process wastewaters, as originally planned. Permeate quality and membrane life were the two major concerns resulting from the pilot tests. RO did remove greater than 99.4 percent of the BOD_5 and could consistently concentrate the candy wastewater to a concentration in excess of 20 percent (20°Brix). It could therefore, be possible to segregate the high strength wastewaters as presently practised and treat the normal process wastewater to a predefined concentration limit (i.e. 20°Brix) using RO. This would enable the permeate quality to meet the by-law limits and potentially extend membrane life, but would result in increased quantities of wastewater concentrate requiring disposal.

The segregated process wastewater was not tested by itself during the RO pilot program and therefore definitive information on membrane performance for this mode of operation is not available. It would be preferable to confirm this operating mode through longer term pilot testing (3 months). It would be imperative to ensure a reliable and cost-effective method for sale/disposal of these larger volumes of concentrated wastewater for the long-term before proceeding with this approach.

Although RO has the advantage of being a physical separation process which is compatible with Dare's operation. uncertainties associated with proceeding to RO system design as demonstrated by this pilot test program still exist.

Recommendations in the August 1989 report suggested that should RO prove to be unsuitable for the Dare Foods application. anaerobic biological treatment should be evaluated in greater detail for treating Dare's high strength wastewaters. Bearing in mind the time schedule being imposed on Dare and the reported uncertainties associated with RO. treatability work on anaerobic treatment is recommended. Anaerobic treatment is a well-established technology for treating similar wastewaters.

Design of an anaerobic treatment system would be possible without a treatability study using existing information. but the design would have to be very conservative. which would be reflected in higher than necessary construction costs. CH2M HILL believes that it would be cost-effective to conduct a treatability program so that design criteria could be established specific to the Dare wastewater. thereby ensuring a reliable and cost-effective design.